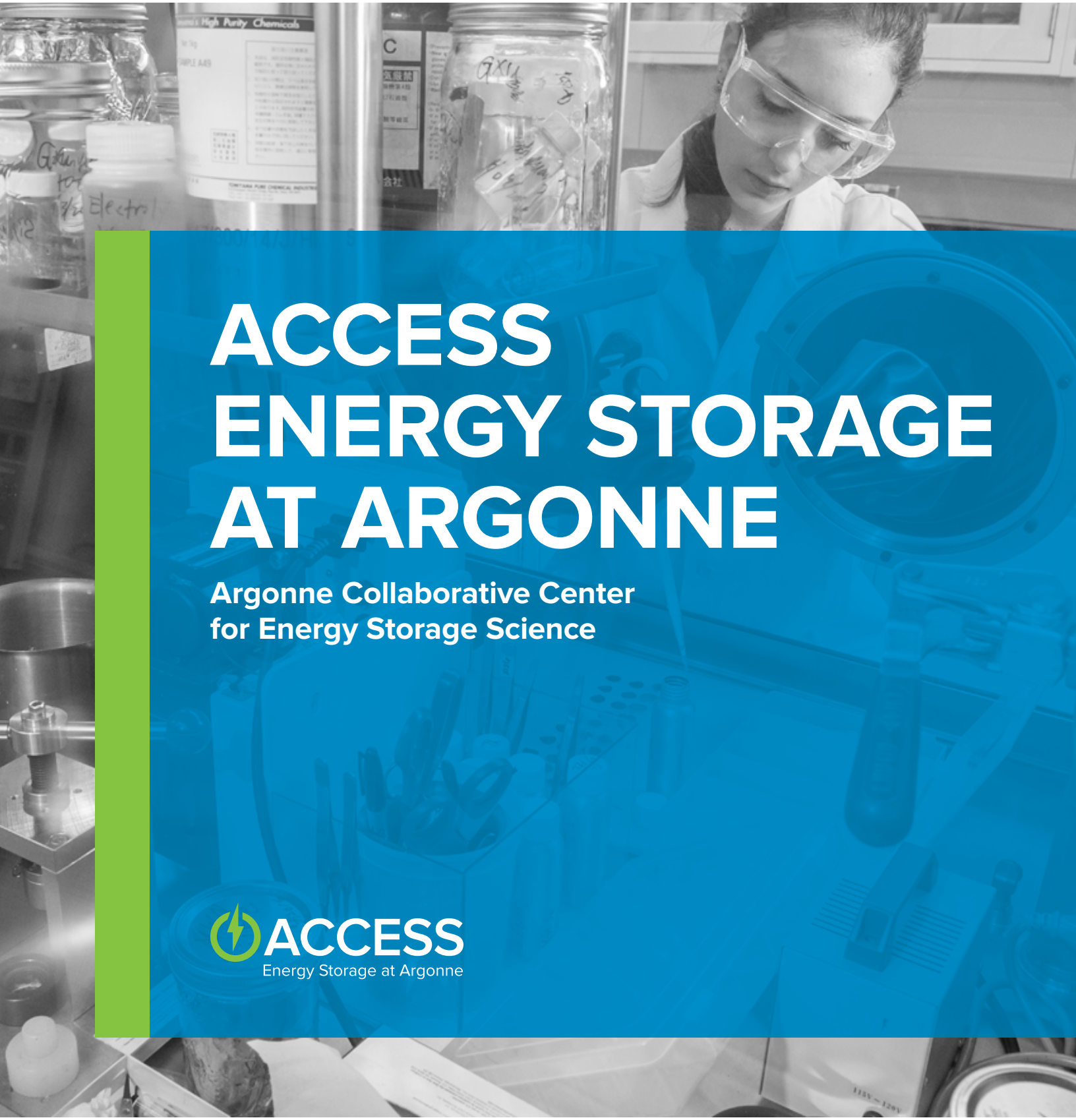
Argonne NATIONAL LABORATORY



ACCESS ENERGY STORAGE AT ARGONNE

Argonne Collaborative Center for Energy Storage Science

ACCESS
Energy Storage at Argonne

THE ABILITY TO STORE ENERGY—HARNESS IT NOW, USE IT LATER—OPENS SO MANY POSSIBILITIES, IT MUST BE CONSIDERED TRULY REVOLUTIONARY.

Argonne unlocks the potential of energy storage, helping public- and private-sector customers create new science and turn these scientific discoveries into solutions.

Stored energy gives the world potential—the potential to be energy secure; the potential to create highly resilient electrical grids; and the potential to create a new paradigm of generating and storing energy through increased adoption of renewable energy and electric vehicles. Energy storage will become the engine that powers the next century of economic growth.

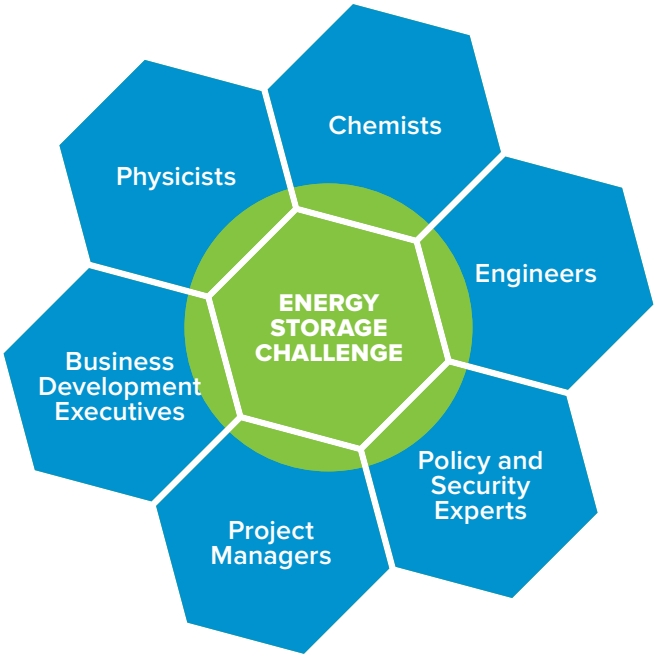
The U.S. Department of Energy's Argonne National Laboratory is one of the key global centers of this revolution with years of cutting-edge research in energy storage technology, leading the way through multiple generations of batteries used in vehicles and the electrical grid to breakthroughs beyond lithium-ion.

The Argonne Collaborative Center for Energy Storage Science (ACCESS) is a collaboration of scientists and engineers from across Argonne that solves energy storage problems through multidisciplinary research.

Lithium-ion battery cells are prepped for testing. With Argonne's state-of-the-art, custom-built equipment, scientists perform simulations to provide information on battery characteristics such as cycle life and calendar life.

ACCESS A UNIQUE COLLABORATIVE CENTER.

Argonne addresses energy storage challenges with a unique combination of resources not found anywhere else. Argonne brings the talent, time savings, unique facilities, and technical capabilities.



ACCESS THE TALENT

Argonne tackles each unique energy storage challenge with a collaborative team assembled from Argonne's 1,600 award-winning and internationally recognized scientists and engineers. The Argonne team represents dozens of disciplines, including chemical sciences and engineering, high-energy physics, materials science, mathematics and computer science, nanoscience and technology, and X-ray science.

Argonne researchers perform an *in situ* X-ray spectroscopy study of a lithium-ion battery system at the Advanced Photon Source.

ACCESS THE TIME

From the very first experiments on high-temperature lithium-sulfur batteries in the late 1960s to today's development of new technologies that move beyond lithium-ion, the road to energy storage innovation has led through Argonne. The collaborative work of Argonne researchers has invigorated the U.S. battery manufacturing industry, aided the transition of the U.S. automotive fleet toward plug-in hybrid and electric vehicles, and enabled greater use of renewable energy.

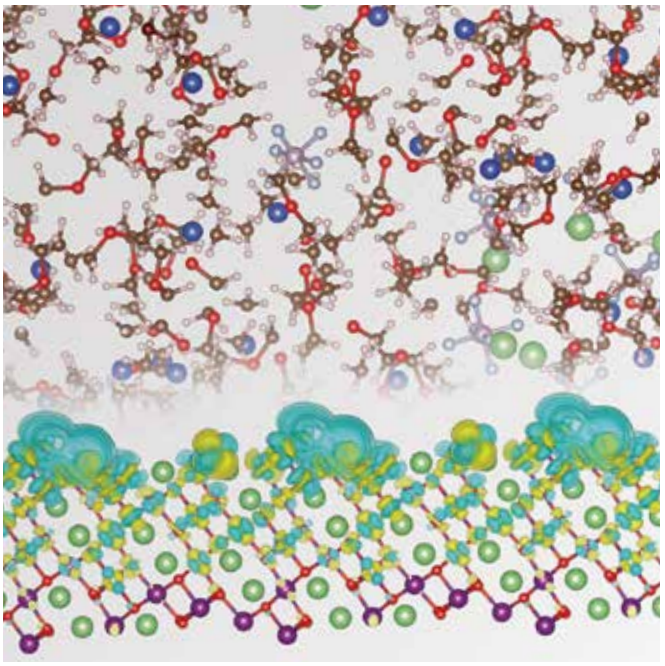
An Argonne researcher prepares a surface area analyzer for the characterization of battery materials.

ACCESS NEW TECHNOLOGY DEVELOPMENT.

Argonne's energy storage proficiency encompasses every point on the spectrum from discovery to commercialization. Whatever your unique challenge, Argonne has a range of processes to help you imagine and design, analyze and compare, question and answer, reject and accept.

DISCOVERY

Research on new materials—electrolytes, electrodes, interfaces—is the first step in developing next-generation energy storage. Argonne researchers make breakthrough discoveries, such as new materials for lithium-ion and beyond-lithium-ion battery chemistries, using a number of Argonne's world-class facilities.



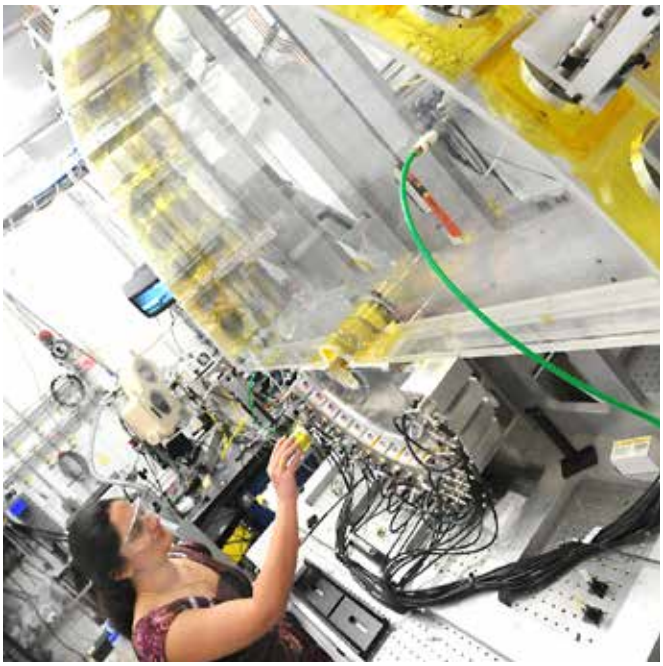
Model of the interface between an electrolyte (darker, above) and an electrode (green crystal structure, below) inside a lithium-ion battery.

MATERIALS CHARACTERIZATION

Leveraging Argonne's Advanced Photon Source, the Argonne Leadership Computing Facility, and other world-class resources, Argonne researchers predict the properties of materials with extreme accuracy.

PROCESS SCALE-UP

After modeling to understand the charge transport process they developed in the laboratory, Argonne researchers modify the process as needed to enable economical commercial-scale production. Making this leap from bench to industrial scale represents one of the most significant hurdles in transitioning new battery materials and technologies to the market.



An Argonne physicist loads a lithium-ion battery into the low-energy resolution inelastic X-ray (LERIX) system for *in situ* measurements at the Advanced Photon Source. This multi-element X-ray scattering instrument is helping Argonne researchers understand the fundamental mechanisms that limit the performance of batteries.

Argonne researchers have developed an improved, scalable process for the synthesis of a lithium-ion battery overcharge protection redox shuttle. Initial discovery amounts of battery materials are small compared to the kilogram-scale amounts needed to validate new battery technologies.

PROCESS AND SYSTEMS MODELING

Drawing upon the Argonne Leadership Computing Facility and other resources, Argonne scientists perform multiscale modeling of charge transport processes in energy storage materials. Argonne's modeling capability for battery systems predicts performance and costs through the battery pack scale. Argonne scientists and engineers are also world leaders in modeling entire grid and vehicle systems, helping to determine how storage technology will enable the systems of the future.

Argonne scientists use state-of-the-art simulation software to model the performance of electric vehicles and their batteries.

CELL FABRICATION

Argonne scientists keep the discovery-to-industry pipeline moving by fabricating commercial-grade, full-size prototype battery cells (pouch and 18650 cells) and battery electrodes necessary to test energy storage materials.

To make a prototype lithium-ion battery, an Argonne chemical engineer lines up positive and negative electrodes on a winder. The two electrodes are then wound together with a separator to create a structure called a "jellyroll."

PERFORMANCE TESTING

Fulfilling the promise of advanced battery systems requires understanding every battery failure—Argonne scientists find the answers by dissecting, harvesting, and analyzing materials from used and previously tested battery cells.

An Argonne researcher examines a cylindrical lithium-ion battery cell to answer important questions about the performance of this type of battery in plug-in hybrid electric vehicles.

Photo courtesy General Motors and the U.S. Department of Energy.


Photo courtesy of U.S. Army National Guard, Staff Sgt. Roby Di Giovine.

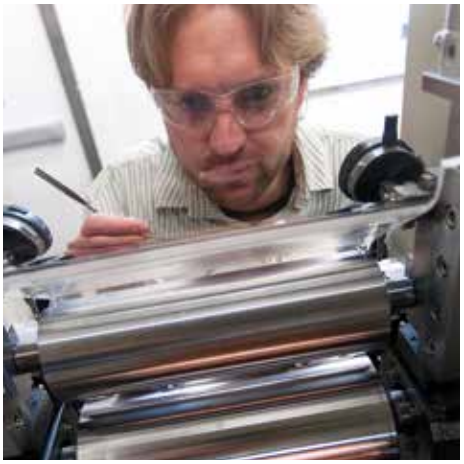
Argonne's ultimate goal is to lead energy storage science and facilitate the transfer of new battery innovations to the marketplace, providing processes, materials, performance testing data, and finished cells to industries including transportation, consumer electronics, and materials manufacture and supply.

Customers working with Argonne—be they small, medium, or large companies; government agencies; national security interests; or entrepreneurs—can realize their potential to bring transformational energy storage to the world.

ACCESS ONE-OF-A-KIND FACILITIES.

Argonne researchers collaborate on a combination of complementary facilities and scientific equipment unmatched in energy storage R&D.

The reaction calorimeter gives Argonne researchers the ability to precisely measure how much heat is generated by a chemical reaction.



Argonne's dry room plays a critical role in the assembly and performance of a finished battery cell.

Information on important battery characteristics such as cycle life and calendar life come from simulations on state-of-the-art, custom-built equipment.

Materials Engineering Research Facility (MERF)

Enables development of manufacturing processes for producing advanced battery materials in sufficient quantity for industrial testing. MERF helps bridge the gap between benchtop science and industrial production by using cutting-edge tools to scale up production of newly discovered materials.

Cell Analysis, Modeling, and Prototyping Facility (CAMP)

Designs, fabricates, and characterizes high-quality prototype cells using high-energy anode and cathode battery materials. CAMP-manufactured cells enable realistic, consistent, and timely evaluation of candidate chemistries in a close-to-realistic industrial format.

Electrochemical Analysis and Diagnostics Laboratory (EADL)

Provides battery developers with reliable and independent performance evaluations of their cells, modules, and battery packs. EADL has the capability to conduct more than 240 concurrent advanced battery studies under operating conditions that simulate various electric vehicle and utility grid applications as well as others. This data is then used for modeling and battery life estimation.

An Argonne scientist analyzes results from battery sample testing that includes characterization in an inert "glovebox" and in a scanning-electron microscope.

Discovery labs provide understanding, at atomic and molecular levels, of the chemical changes that occur during battery charging and discharging.

Post-Test Facility

Assists with difficult problems related to battery failure modes. Designed to handle air-sensitive materials, such as those from lithium-based or sodium-based battery technologies, the facility uses a mixture of materials science and wet-chemistry techniques. Facility staff has direct experience evaluating pouch and hard-case cells. With knowledge of the causes of performance decline and/or failure, battery developers work to improve the life and performance of batteries.

Electrochemical Discovery Laboratory (EDL)

Synthesizes high-quality materials for testing in beyond-lithium-ion batteries, and characterizes their properties with state-of-the-art analytical techniques. These labs make it possible for scientists to synthesize liquid electrolytes with unparalleled control over water content and other impurities.

Argonne's energy storage researchers also benefit from access to the lab's other cutting-edge resources.

Argonne Leadership Computing Facility (ALCF)

The ALCF is half of the leadership computing facility supported by the U.S. Department of Energy, and is home to Mira, one of the fastest supercomputers in the world. ALCF staff provide expertise and assistance to support user projects to achieve top performance of applications and to maximize benefits from the use of computing resources.

Advanced Photon Source (APS)

The APS provides the brightest storage ring-generated X-ray beams in the Western Hemisphere for research in materials science, chemistry, biology, physics, earth and planetary science, and environmental science.

Center for Nanoscale Materials (CNM)

The CNM develops and maintains unique capabilities for electron beam characterization and applies those capabilities to solve materials problems in three major areas: materials research, technique, and instrumentation.

ACCESS PROVEN CAPABILITIES.

Argonne has demonstrated achievement in meeting a spectrum of energy storage challenges and has amassed a portfolio of more than 125 patented advanced cathode, anode, electrolyte, and additive components for lithium-ion, lithium-air, lithium-sulfur, sodium-ion, and flow batteries.


Property
U.S. Government

ACCESS A COMPETITIVE ADVANTAGE.

Today's changing business climate has led companies to devote research dollars to product development, with a reduced focus on basic science research.

By developing tailored teams of experienced researchers who collaborate on world-class equipment in one-of-a-kind facilities, Argonne offers companies an affordable, manageable alternative to increase their stake in scientific discovery.

The increasing complexity of scientific challenges requires access to resources that private industry—particularly small and medium-sized businesses—cannot necessarily muster. Argonne's time, talent, and tools represent billions of dollars invested in energy storage R&D; Argonne turns this investment into a competitive advantage for any company looking to solve a unique energy storage challenge.

HOW YOUR COMPANY CAN WORK WITH ARGONNE

Argonne works with industry and governmental partners to solve enduring R&D challenges, identify commercialization opportunities, license new applications, and introduce transformational technologies to the marketplace.

Argonne offers multiple processes for collaborating with outside groups to accommodate both small and large firms. Licensing and contractual agreements vary based on the particular situation; we will work with you to meet specific needs, including concerns about intellectual property. For additional information on how to work with Argonne, visit www.anl.gov/technology/partnerships.

Licensing agreements—with leading companies such as General Motors, BASF, LG Chem, General Electric, and Toda America—to mass produce Argonne's patented materials for advanced batteries have led to the construction of new plants and the creation of jobs in the United States.

Representatives from the U.S. Department of Energy and Argonne joined federal, state, and local officials, as well as representatives and BASF personnel, for a ribbon cutting at the company's first-of-its-kind, $50 million Elyria, Ohio, facility. Photo courtesy of BASF Corporation.

LET ARGONNE HELP UNLEASH THE POTENTIAL OF YOUR ENERGY STORAGE SOLUTION.

ACCESS
Energy Storage at Argonne

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Argonne NATIONAL LABORATORY

ABOUT ARGONNE NATIONAL LABORATORY

- U.S. Department of Energy research facility
- Operated by the University of Chicago
- Midwest's largest federally funded R&D facility
- Located in Lemont, IL, about 25 miles (40 km) southwest of Chicago, IL (USA)
- Conducts basic and applied research in dozens of fields
- Unique suite of leading-edge and rare scientific user facilities

www.anl.gov

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